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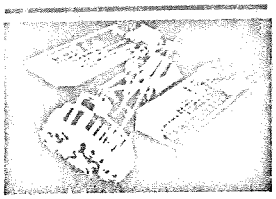
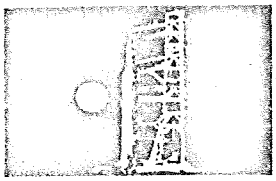
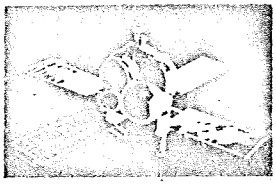
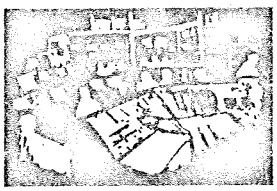
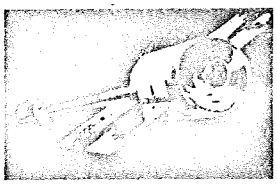
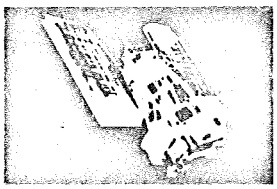
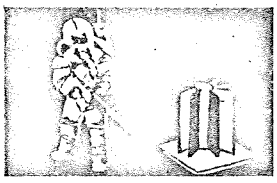
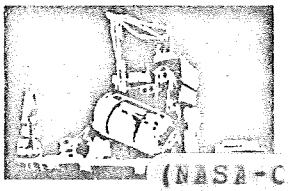
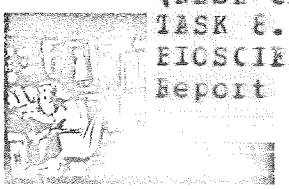
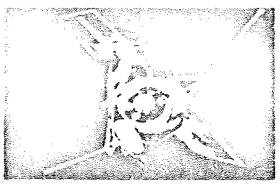
DOC. GE NO. 70SD5415

IMBLMS
PHASE B4

ADDITIONAL TASKS
TASK 8.0

IMBLMS (EDU) Incorporation Of Biosciences Measurement Capability

FINAL REPORT

Manned Spacecraft Center
Houston, Texas 77058

IMBLMS

OFFICE OF PRIME RESPONSIBILITY

DE2

GENERAL ELECTRIC

GE NO. 70SD5414
OCTOBER 29, 1971

FINAL REPORT

FOR

TASK 8.0

IMBLMS (EDU) INCORPORATION OF BIOSCIENCES MEASUREMENTS

IMBLMS PHASE B-4
ADDITIONAL TASKS

CONTRACT NAS9-10741

GENERAL ELECTRIC COMPANY
SPACE DIVISION

LIST OF TABLES

1.0 SUMMARY

This task was performed to determine the changes that would be required in the IMBLMS Engineering Development Unit (EDU), in order to accommodate the Life Sciences measurement requirements in the NASA "Blue Book". The primary extensions in the utility and capability of the EDU are those to accommodate biological research on other representative life forms ranging from micro-organisms to large vertebrates in addition to its medical capabilities. Experiment-peculiar equipments to effect that extension in capability was considered in this study as a requirement on the experimenter furnished equipment rather than on the EDU. Common-purpose functions normally associated with a life sciences laboratory, for instance: bio-chemical analysis, specimen handling, data management, and experiment subject observation were considered as EDU requirements and were matched against the previously defined EDU capabilities. Where added capabilities were found necessary, the needed modifications or additions to the EDU equipment were established. The Budgetary costs of these changes were defined on the basis of previous experience in the development, construction and modification of similar types of equipment.

The analysis showed it is both feasible and practical to use the EDU as a facility to conduct research in the Life Sciences as defined in the NASA "Blue Book", with modest increases in capability. The greatest equipment and cost impact was determined in terms of additions and modifications to the equipment for handling biological specimens, and in the upgrading of the capability for chemical analysis. In contrast, no additions or modifications to the EDU were found necessary in the data management area. (Effects of usage rates and duty cycles that are dependent on the probable time lines associated with specific - and yet undetermined - experemental programs could not be considered.) The total cost of the changes to the EDU were estimated at approximately $2.8 million, including development costs, first unit costs and costs of management and integration into the system.

2.0 INTRODUCTION AND SCOPE

2.1 TASK OBJECTIVES

This report presents the results of Phase B4 Additional Task 8, "IMBLMS (EDU) Incorporation of Biosciences Measurement Capability". This task was performed to determine the requirements and approach for incorporating into the IMBLMS Engineering Development Unit (EDU) the measurements defined in and derived from the NASA "Blue Book" Life Sciences, Volume VIII, reference Earth Orbital Research and Applications Investigations, of January 15, 1971.

2.2 BASELINE DOCUMENTS

Baseline documents for this study consisted of:

- NASA IMBLMS Phase C Statement of Work (draft) of 1 July 1971, used for definition of the EDU program and technical requirements.

- GE Phase B4 EDU preliminary design, used (with changes indicated by the Phase C Statement of Work draft) as the design baseline from which needed additions or modifications could be defined.

- Phase B4 Added Tasks, Task 7 "Phase C Preliminary Planning Study", used as the source of technical and programmatic planning response to the Phase C draft Statement of Work including identification of changes from the Phase B4 preliminary design.

2.3 KEY GUIDELINES

Several guidelines and assumptions were adopted, with NASA concurrence, for the conduct of this task. Summarized, the are:

- Only those required measurements and techniques stated in or derived through interpretation of facility requirements of the "Blue Book" were utilized in the study. Items related to future capability growth beyond the scope of experimentation characterized in the "Blue Book" were not considered as part of the EDU requirements. (Example is holography, listed as a "core" item but not supported by examination of the experimentation needs.)

- Experiment-specific equipment such as animal cages, restraint apparatus, holding fixtures, specialized sensors, and waste managmenet facilities for the various biological species are not included in the "Blue Book" derived requirements for the EDU. These items are determined primarily by the specifics of experiments not yet defined, and have a low potential for common application across experiments, so attempting to assign them to the IMBLMS was not deemed effecitve. (This corresponds to the experimenter "suitcase" approach to be interfaced with and supported by the IMBLMS, as visualized by Dr. W. Hull of MSC.)

- Cost estimates are approximations based upon judgement of persons and/or organizations experienced in the fields/equipments being costed, rather than definitized quotes. They are in accordance with the standards associated with the EDU program and carry through incorporation into the EDU system.

2.4 ELEMENTS OF THE STUDY

The principal elements of this study, based on the subtasks of the Task, are:

- Compilation of the Bioscience measurements derived from the FPE's (Functional Program Elements) and core capability from the Blue Book into a requirements listing.
- Definition of the approaches to conduct the Bioscience measurements.
- Identification of the requirement for and degree of modification of the EDU to satisfy these requirements and approaches.
- Identification of additional EDU equipments and functions to satisfy these requirements and approaches.
- Determination of interface and system impact of adding the Bioscience measurement capability.
- Preparation of budgetary estimates and rationales for the additions and changes.
- Preparation of final report.

3.0 ANALYSIS

3.1 COMPILATION OF "BLUE BOOK" BIOSCIENCE MEASUREMENTS

Measurement requirements were compiled for the following Functional Program Elements (FPE) in the Life Sciences discipline:

(L-1) Medical Research Facility

(L-2) Vertebrate Research Facility

(L-3) Plant Research Facility

(L-4) Cells and Tissues Research Facility

(L-5) Invertebrate Research Facility

(L-6) Life Support and Protective Systems

(L-7) Man-System Integration

Two types of requirements were considered: FPE specific, and "CORE". The FPE specific are those that can be derived from the descriptions and tabulations in the "Blue Book" relative to specific experiments; whereas the "CORE" are those which are identified in the "Blue Book" as related to common-purpose capabilities "serving a broad spectrum of experimental areas in several FPE's." That compilation contained numerous duplications and areas of overlap, due to commonalities of requirements between FPE's beyond those identified as part of the "CORE". In addition, there are cases where several requirement items may be implemented through use of the same equipment, and thus represent a single demand on the system. These commonality considerations led to the next step in the study, a synthesis of all the aforementioned measurement requirements into a non-overlapping set which is much more meaningful and manageable in terms of the objectives of this Task 8 study.

3.2 SYNTHESIS OF MEASUREMENT REQUIREMENTS

The synthesized set of requirements was developed through an iterative process involving the "Blue Book" guidelines and the application of scientific judgement by the task participants. Using the objectives related with each of the Functional Program Elements in the "Blue Book", a synthesis was developed by listing the measurements and functions generally considered as necessary by the participating life scientists in performing environmental studies to satisfy those objectives. The order in which the FPE's were analyzed was inverse with respect to the degree of correlation between the IMBLMS EDU capabilities had FPE requirements; thus, the Cells and Tissues Research Facility FPE was treated first, since it was expected to have the least correlation with the EDU requirements; the Medical Research Facility FPE was analyzed last, since it was expected to have the greatest correlation with the EDU. The requirements thus derived were then checked against the original compilation of "Blue Book" requirements, and any basic differencies were rectified.

It is seen that the FPE requirements in the "Blue Book" were not used as the only source of information for the determination of the synthesized list of measurement/functional requirements. Independent scientific judgement was applied to generate a realistic listing. The following comments concerning the "Blue Book" requirements are to clarify the need for this type of synthesis:

a. The Life Science portion of the Blue Book describes a candidate concept of a facility; it does not describe an experiment program. Part A is a general introduction; Part B lists multipurpose equipment, including the CORE; Sections 1 thru 7 describe sub-facility concepts to accomplish the FPE's, e.g., Vertebrate Research Facility, Plant Research Facility, etc. The equipment descriptions within the CORE and FPE facilities are not amenable for direct comparison with the EDU equipment since the organization and identification of equipments differs greatly and masks commonalities which may exist. Rather, the functional capabilities and measurements are a better basis for matching since the commonalities and differences can be compared directly.

b. The measurement descriptions in the Blue Book are abbreviated in the Experiment Requirement Summaries, with the entries in these summaries subject to a wide range of interprelations depending on the specific nature of the experiment at hand. Insight and accurate interpretation can be made only for those experiments that are defined in the "Blue Book" - but only one representative experiment is defined in each class of experiments (e.g., The Medical Research Facility FPE has eleven classes of experiments, such as Neurological Function, Cardiovascular Function; eleven corresponding representative experiments defined out of thirty-eight identified experiments).

c. The CORE contains many items that give the Life Sciences Facility an expanded capability undoubtedly designed to permit the performance of a broad spectrum of experimentation even beyond that which is implied by the experiments which are identified in the text. (For instance, in the Visual Records and Microscopy Unit of the CORE is included a Holograph weighing 115 pounds and consuming 500 watts of power). Equipment items such as this may not be essential to the performance of a viable initial experiment program using IMBLMS, therefore, they were not considered as a requirement based on measurements necessary to accomplish an initial experiment program.

Methods or approaches for the implementation of the measurements resulting from the synthesis step described above were then determined. In performing this subtask, particular attention was given to those techniques and approaches incompassed in the design of the EDU, in order to ensure consideration of the full IMBLMS capabilities. Thus, if a particular device in the EDU was partially or fully capable of performing a given measurement, that approach was selected. In cases where the applicability of the EDU equipment or techniques were tenuously related to the specific measurement needs, that approach was not considered.

The measurement lists for accomplishing each FPE (prior to combination into a single list) together with pertinent characteristics and other notes as to implementation are contained in Tables 3.2-1 through 3.2-7 as follows:

Table 3.2-1: FPE L-1 Medical Research Facility Measurements - Are tabulated by experiment class

Table 3.2-2: FPE L-2 Vertebrate Research Facility - Because of overlap with other FPE's, amplification of the measurement list with characteristics was not required.

Table 3.2-3: FPE L-3 Plant Research Facility

Table 3.2-4: FPE L-4; Cells and Tissues Research Facility

Table 3.2-5: FPE L-5; Invertebrate Research Facility

Table 3.2-6: FPE L-6; Life Support and Protective Systems

Table 3.2-7: FPE F-7; Man-System Integration

The single, combined non-duplicative measurement list, together with approaches for accomplishment and other comments, is contained within Table 4-1 and discussed in Section 4.0 - Results.

3.3 EFFECT ON EDU

Each measurement requirement was categorized according to the capability of the EDU to perform that measurement. Three categories were considered:

1. Measurements that can be performed fully by using the equipment capabilities of the EDU.

2. Requirements for measurements in this category can only be satisfied partically, and require modification of the EDU equipment as presently defined.

3. Requirements for measurements in this category require the addition of new equipment to the EDU.

In making the categorizations, two baseline documents were applied:

1. The IMBLMS Phase B4 Final Report (Document GE Number 70SD5386) provided the baseline of the EDU preliminary design including measurements and measurement requirements, system design and modules identification, and preliminary module designs.

2. Phase B4 Added Tasks Task 7, Phase C Preliminary Planning Study, Subtask 1 EDU System Design, identified the measurements and modules in the EDU based on the 1 July 1971 draft Statement of Work. While some differences did exist from the Phase B4 preliminary design, the identification in this task was to an item rather than a preliminary design level so that the preliminary design was the primary base.

FPE: L-1 MEDICAL RESEARCH FACILITY
EXPERIMENT CLASS: NEUROLOGICAL FUNCTION

TABLE 3.2-1
COMPILATION OF BIOSCIENCE MEASUREMENTS

MEASUREMENT	CHARACTERISTICS	NOTES
ROTATING LITTER CHAIR ANGULAR VELOCITY	3 BILEVEL DISCRETE CHANNELS	10 SAMPLES/SEC.
ROTATING LITTER CHAIR MOTOR CURRENT	1 CHANNEL	ASSUME ANALOG, 320 SAMPLES/SEC.
SUBJECT ANGULAR ACCELERATION	6 ANALOG CHANNELS	ASSUME ANALOG, 1 SAMPLE/SEC.
HEAD MOTION	4 ANALOG CHANNELS	ASSUME ANALOG, 1 SAMPLE/SEC.
AMBIENT TEMPERATURE	1 ANALOG CHANNEL	1 SAMPLE/SEC.
SUBJECT REMOTE SIGNALS	23 BILEVEL DISCRETE CHANNELS	
VOICE RECORDS	1 ANALOG CHANNEL	ASSUME 100-3k Hz ADEQUATE
EEG	6 ANALOG CHANNELS, RANGE 6-3 m.v., SMALLEST INCREMENT 0	

FPE: L-1
EXPERIMENT CLASS: RENAL FUNCTION

TABLE 3.2-1 (Cont'd)

MEASUREMENT	CHARACTERISTICS	NOTES
pH AND RADICAL CONCENTRATIONS IN HAND		
pH AND RADICAL CONCENTRATIONS IN URINE		
RENAL BLOOD FLOW	SPECTROPHOTOMETRIC/REFRACTION MEASUREMENTS	MEASURED BY PARA-AMINOHIPPURIC ACID (PAH) CLEARANCE
(RENAL FUNCTION)		
(RENAL CALCULUS FORMATION)		
(RENAL INFECTION)		
SPECIMEN MASS		
BODY MASS		
URINE SAMPLE & VOLUME MEASUREMENT		
		OTHER REQUIREMENTS:
		1. FREEZER IS REQUIRED 15 CU. FT.
		2. MICROCENTRIFUGE (10 LBS)
SUGGESTED REQUIREMENTS (NOT BLUE BOOK DERIVED)		
FLUID TRANSFER EQUIPMENT		
BLOOD ANALYSIS EQUIPMENT(FOR SERUM ELECTOLYTES)		
MICROSCOPE		
COLONY COUNTER		
HISTOLOGY KIT/SLIDE CABINET		
HISTOLOGICAL STAINING SYSTEM		

FPE: L-1
EXP. CLASS: MUSCULO- SKELETAL FUNCTION

TABLE 3.2-1 (Cont'd)

MEASUREMENT	CHARACTERISTICS	NOTES
RESPINRATION RATE	RATE: 8-40/MIN, 1 CHANNEL REQUIRED	
HEART RATE	RATE: 40-180 MIN., 1 CHANNEL REQUIRED	
BODY TEMPERATURE	95-105°F, SMALLEST INCREMENT: 0.1°F	
BLOOD PRESSURE	RANGE: 300/150 - 100/60	
ERGOMETER OUTPUT	RANGE: 50-300 WATTS, SMALLEST INCREMENT: 10 WATTS	
ERGOMETER SPEED	RANGE: 40-90 r.p.m., 10 r.p.m.	
METABOLIC (OUTPUT)		
VOICE RECORDS		
SUGGESTED REQUIREMENTS (NOT BLUE BOOK DERIVED)		
REFRACTOMETER		
BLOOD GAS ANALYSIS		
PHYSIOLOGICAL GAS ANALYSIS		

EXPERIMENT AREA: HEMATOLOGIC FUNCTION

MEASUREMENT	CHARACTERISTICS	NOTES
RED CELL MASS	Cr^{51} INJECTION METHOD, RADIOACTIVE COUNTING	RELATES TO RED CELL PRODUCTION, DISTRIBUTION, AND DESTRUCTION
PLASMA VOLUME	I^{125} USED, RADIOACTIVE COUNTING	PLASMA VOLUME CHANGES TO BE PERFORMED SIMULTANEOUSLY WITH RED CELL MASS MEASUREMENTS. IN-FLIGHT HEMATOLOGY MAY BE REQUIRED

FPE: L-1
EXPERIMENT CLASS: CARDIOVASCULAR FUNCTIONS

TABLE 3.2-1 (Cont'd)

MEASUREMENT	CHARACTERISTICS	NOTES
LOWER BODY NEGATIVE PRESSURE DIFFERENTIAL	RANGE: 0-60 mm Hg, SMALLEST INCREMENT = 0.1 mm Hg	SPECIFIES DIGITAL
VOLUME, RIGHT & LEFT LEG	RANGE: 0-10%, SMALLEST INCREMENT = 0.1%, 1 Hz RESPONSE	SPECIFIES ANALOG
BLOOD PRESSURE	RANGE: 0-160 mm Hg, SMALLEST INCREMENT = 1mm Hg.	BLOOD PRESSURE CUFF
AUDIO INPUT	BILEVEL DISCRETE, FREQUENCY = 2/MIN	ANALOG INPUT TO EARPHONE
VECTORCARDIOGRAM (VCG)	RANGE: 0-5 mv., SMALLEST INCREMENT = 0.1 mv, 100 Hz RESPONSE	ANALOG SPECIFIED
BODY TEMPERATURE	RANGE: $98.6^{\circ}F \pm 5^{\circ}F$, SMALLEST INCREMENT = $0.1^{\circ}F$	ANALOG SPECIFIED
AMBIENT PRESSURE	RANGE: 14.7 psi - SMALLEST INCREMENT 0.05 psi	DIGITAL SPECIFIED
AMBIENT TEMPERATURE	RANGE: $72^{\circ}F \pm 3^{\circ}F$, SMALLEST INCREMENT $0.1^{\circ}F$	DIGITAL SPECIFIED
VOICE RECORDS	100-3kH$_3$ RESPONSE	ANALOG
		SUBJECT IDENTIFICATION & TIMING ARE SPECIFIED ALSO.
ARTERIAL PRESSURE		
INTRAOCULAR BLOOD PRESSURE		
BALLISTOCARDIOGRAPH		
PERIPHERAL ARTERIOLAR REACTIVITY		

FPE: L-1

EXPERIMENT AREA: MICROBIOLOGY AND INMUNOLOGIC FUNCTION

TABLE 3.2-1 (Cont'd)

MEASUREMENT	CHARACTERISTICS			NOTES
	NORMAL RANGE (2σ)	EQUIPMENT OR TECHNIQUE	SAMPLE SIZE	
A. HUMORAL IMMUNITY				
1. TOTAL PLASMA PROTEINS	6-0 - 8.5%	GOLDBERG TEMPERATURE -COMPENSATED REFRACTOMETER.	0.2 ml PLASMA	
2. PLASMA GLOBULINS		ELECTROPHORESIS USING SPINCO MICROZONE CELLULOSE-ACETATE TECHNIQUE.		
ALBUMIN	3.35-5.17 g%			
α1-GLOBULIN	0.16-0.36 g%			
α2-GLOBULIN	0.45-1.05 g%			
β GLOBULIN	0.55-1.04 g%			
γ GLOBULIN	0.62-1.52 g%			
3. PLASMA IMMUNOGLOBINS		IMMUNOELECTROPHORESIS USING AN AGAR-GEL MICROTECHNIQUE.	8 μl PER PROTEIN DETERMINATION	
IgG/ G-GLOBULIN	700-1700 mg%			
IgA/ A-GLOBULIN	70-350 mg%			
IgM/ M-GLOBULIN	70-120 mg%			
α2M-GLOBULIN	130-370 mg%			
TRANSFERRIN	200-440 mg%			
β1A-C'3 COMPONENT	40-140 mg%			
4. PLASMA ENZYME MURAMIDOSE (LYSOZYME)	$\simeq$6 μg/ml	PROCHOP TURBITIMETRY		
B. CELLULAR IMMUNITY				
1. LYMPHOCYTES		NYLON-RECTICULUM COLUMN TECHNIQUE	15 ml OF HEPARINIZED VENOUS BLOOD	
C. COAGULATION STUDIES		FIBRINOLYTIC ACTIVATION AND INHIBITION	7.5 ml CITRATED PLASMA 5.0 ml URINE	
SUGGESTED REQUIREMENTS				
FREEZER				
PHOTOGRAPHIC CAMERA				

FPE: L-1
EXPERIMENT CLASS: CLINICAL - THERAPEUTIC FUNCTION

TABLE 3.2-1 (Cont'd)

MEASUREMENT	CHARACTERISTICS	NOTES
ELECTROCARDIOGRAM		
VECTORCARDIOGRAM		
CARDIOTACHOMETER OUTPUT		BLUE BOOK STATED INSTRUMENT UNDER DEVELOPMENT.
TIME ELAPSED		TIMER REQUIRED
ERGOMETER OUTPUT	50-300 WATTS	
ERGOMETER SPEED	40-90 RPM, SMALLEST INCREMENT: 10 RPM.	

FPE: L-1
EXP. CLASS: NUTRITION & METABOLIC FUNCTION

MEASUREMENT	CHARACTERISTICS	NOTES
URINE SAMPLE & VOLUME MEASUREMENT		REQUIRES URINE SAMPLE FREEZER
FECES SAMPLE & MASS MEASUREMENT		REQUIRES FECAL COLLECTOR & VACUUM DRYER
BODY MASS		
FLUID INTAKE		
BLOOD ANALYSIS		

EXPERIMENT AREA: ENVIRONMENTAL FACTORS

MEASUREMENT	CHARACTERISTICS	NOTES
COLONY COUNT		
MICROBIAL AIR SAMPLING		

L-2: VERTEBRATE RESEARCH FACILITY

TABLE 3.2-2
COMPILATION OF BIOSCIENCE MEASUREMENTS

MEASUREMENTS

TV Monitoring
ECG
EEG
EMG
Respiratory Rate
CO_2 Production
O_2 Consumption
Thermal Output
Photographic Record
Voice Records
Food Consumption
Water Consumption
Musculoskeletal Tonus
Urine Output
Feces Output
Hematologies
Chemistries
Serologies
Radiochemistries
Cytological/Histological Analysis
Bacterial Counts
Bacterial Assay
Blood Pressure
Blood Gases:
- pO_2
- pCO_2
- pH

Total Bodywater
Total Body Weight
Extracellular Fluid
Ambient Conditions
- . pO_2
- .pCO_2
- .pNH_3
- .pH_2O
- .Temperature
- .Noise
- .Vibration

Ambient Conditions (continued)
- .Acceleration
- .Radiation
- .Illumination Level

Urine Analysis

Radiobiological Measurements

Cardiovascular Measurement
- .Heart Rate
- .EKG
- .Arterial & Venous Pressure
- .Arterial & Venous Blood Flow

Hemodynamic Measurements
- .Blood Volume
- .% Hemoglobin
- .Plasma protein
- .Cardiac Output
- .Arterial & Venous pO_2

Metabolic
- .Ca++ Balance
- .H_2O Balance
- .N_2 Balance
- .Caloric Balance
- .Body Temperature

L-3: PLANT RESEARCH FACILITY

TABLE 3.2-3
COMPILATION OF BIOSCIENCE MEASUREMENTS

MEASUREMENT	CHARACTERISTICS	NOTES
Monitoring TV	Color, B&W	
Ambient Measurements - Plant Holding Unit		
. Temperature	Range: 293°K to 313°K; Precision: ± 1°K	
.Relative Humidity	Range: 40°to 90%; Precision ± 5% of setting	
.Atmospheric Pressure	Range: 740 to 780 mm. Hg.	
.pO_2	Range: 135 5o 165 mm. Hg.	
.pN_2	130 db max.	
.pNH_3	10^{-4}G peak to peak, frequency 10-5000 cps (estimated)	
.pH_2O	Range: 0-200 foot-candles	
.Noise	Average dimension = 25 cm, suggested range 0-50 cm	
.Vibration Level	10^{-2} to 10^{-5}, cumulative record of G vs time is required.	Total illumination + UV intensity measurements required.
.Illumination Intensity	Range: 590 - 600 mm Hg.	Optical measurement methods prepared, to prevent perturbations.
Plant Size	Range: 0.2 to 7.6 mm Hg.	
Gravity Level (Steady State)		pO_2 and pCO_2 measurements to be adequate for continuous measurement of gas exchange for photosynthetic, respiratory and assimilatory analysis.
Radiation Level	Spectrum and intensity associated with orbit envelope between 28°-55° inclination, attitudes 150-300 n. mi.	Dosimeters to identify particulare
Biochemical Analysis	Will include biosynthesis, rate of growth factors, auxin, gibberellin, cytokinin, ethyline	
Photographic Record	Still photography, time-lapse photography	
Stress/Movement	Strain gauges, high sensitivity	
Radiobiology Measurement	Capability for radioisotope tracer studies	
Biocentrifuge Speed		
Specimen Fixation		
Microscopy (see CORE)		

L-3: PLANT RESEARCH FACILITY (Continued)

TABLE 3.2-3
COMPILATION OF BIOSCIENCE MEASUREMENTS (Cont'd)

* MEASUREMENT	CHARACTERISTICS	NOTES
Endogenous Plant Rhythms		
Biochemical Changes	Changes in saponifiable & non-saponifiable lipids, proteints & carbohydrates	
Morphological measurements		Measurementsprior to quick freezing for preservation.
Growth, development & epinasty	Photographic records	
Biosynthesis	Auxim, gibbercellin, cytokinin, ethylene using radiometric tagging	May be performed on the ground facility after return
Enzyme activity (e.g. peroxidase)		"
Histological examination of tissue		"
Cytological analyses of cell types		"
Pathological and anatomical examination		"
Changes in polarity	In cell, tissue or organs	"
Position of cell organelles		"
Amino Acid Metabolism	Includes study of the characterization of enzymes which catalyze the methionine, and their derivatives	
Correlation of Proline & Homologs		
Biosynthesis & Catabolism of essential amino acids		
Amount & composition of free amino Acid Pool		
Cellular calcium distribution		
Cellular membrane function	Solute uptake rate, osmotic potential, cell water potential,	
Synthesis rate of DNA, RNA & proteins		
Anamtity of lignin, cellulose, pectic & cuticular substances		

*This listing shows measurements concerning the Role of Gravity in Plant Life Cycles + Processes, specifically Metabolism & Energetics in Hypogravity.

L-4: CELLS & TISSUES RESEARCH FACILITY

TABLE 3.2-4
COMPILATION OF BIOSCIENCE MEASUREMENTS

MEASUREMENT	CHARACTERISTICS	NOTES/COMMENTS
Monitoring TV	Color, B&W	
Ambient Measurement - Incubator		
. Temperature	$310^{o}K$ to $78^{o}K$	
. Total Atmospheric Pressure	750-770 mm Hg.	
. pO_2	140-160 mm Hg.	
. pCO_2	less than 3.0 mm Hg.	
. pCO	less than 0.01 mm Hg.	
. pNH_3	less than 0.01	
. pH_2O		
. Noise	130 db max.	
. Vibration	10^{-4} G peak to peak, frequency 10-5000 cps (estimated)	
. Illumination	20 - 100 St. candles	
. Radiation Level	Spectrum and intensity associated with orbit envelope between 28^{o} - 55^{o} inclination, altitudes 150-300 n. mi:	
Microscopy (see CORE)		
Photographic Record	Still photography, cine (with microscope attachments)	
Gravity Level	10^{-2} to 10^{-5} G	
Substrate pH		
Histological Analysis		
Biochemical Analysis		
Morphological Examination		
Radiobiological Analysis		

L-5: INVERTEBRATE RESEARCH FACILITY

TABLE 3.2-5
COMPILATION OF BIOSCIENCE MEASUREMENTS

MEASUREMENTS	CHARACTERISTICS	NOTES/COMMENTS
Monitoring TV	Color, B&W	
Ambient Measurement	10^{-2} to 10^{-5}G	
.Temperature	Range 283 to 333°K, Precision ± 1°K	
.Total Atmospheric Pressure	750-770 m.m. Hg.	
.pO_2		
.pCO_2		
.pH_2O		
.Noise		
.Vibration		
.Radiation Level	Dosimeter	
.Lighting	0-120 St. Candles	
Microscopy (see Core)		
Photographic Record	Still + time-lapse photography	
Gravity Level	Range: 10^{-2} to 10^{-5} G	
Respiration Rate	On insects such as Periplaneta Americana	
Histologies		
Eclosion Rate		
Chemical Analysis	Includes on-board analysis of gas samples for insect holding units	
Mass Measurement	Milligram precision	
Radiobiological Measurements	Utilizes isotopic tracers	

TABLE 3.2-6
COMPILATION OF BIOSCIENCE MEASUREMENTS

FPE L-6: LIFE SUPPORT AND PROTECTIVE SYSTEMS

Instrumentation required to satisfy the requirements of this FPE are considered a part of the experiental components, assemblies and subsystems to be tested. Measurements obtained through that experiment - peculiar equipment will consist of standard fluid pressures, temperatures and flow rates that are already accounted for in Table 3.2-1 thru 7.

TABLE 3.2-7

COMPILATION OF BIOSCIENCE MEASUREMENTS

MEASUREMENTS	CHARACTERISTICS	NOTES/COMMENTS
Centrifuge Speed	0-4.9 radians/sec.	
Metabolic Analysis	O_2 and CO_2 breadth; 1-30000 cal/min.,	Portable analyzer
Impact Force	Dynamic acceleration or strain-gage measurements (0-200 ft-lb)	Crevman generated impact forces during mobility tests
Acceleration	Multiple simultaneous acceleration readings (nominal: 13) (0.1 - 10G)	Crevman accel/decel during mobility tests
Event Time	Identified times of events such as impact occurrence	
Visual Measurements	Requires automatic sequencing of pre-programmed stimuli & recording of response scores.	
. Acuity	Measured in millimeters (3 digits). Precision: to one decimal point	
.Depth Perception	Measured in percent of distance travelled	
.Brightness Threshold	Candeller/m^2 (3 significant digits)	
.Visual Field	90^operipherally in all 12 meridians	
.Flicker Fusion Frequency	20-50 Hz.	
.Phorias	Measured in radians from center of fixation	
.Glare Recovery	cd/m^2 and seconds of time	
.Color Perception	Up to 99 hues	
.Dark Adaptation	cd/m^2, seconds of time	
Auditory Measurements	Presents sequential pure-tone stimuli from 500-6000 Hz	Recommended instrument: Rudmose ARJ - YA Bekesy type audiometer
.Absolute Threshold		
.Pitch Discrimination	100-10000 Hz, 0.0002 dyne/cm^2	
.Temporal Acuity	Duration 0.5-1 sec., Interval: 0-250 m sec; Level 0-50 db.	
.Speech Intelligibility	0-2000 H_3: $\pm$ 10Hz; 2000 Hq up: $\pm$ 20Hg	
.Sound Localization/Motion Discrim.		
Cultaneous Pressure Threshold		
Psychomotor Processes:	Pre-programmed stimuli such as lights, meters, and CRT	Steadiness
.Fine Motor Abilities		
.Complex Motor Abilities		
.Gross Body Coordination	Simple and complex	Tracking
.Continuous Control		
.Reaction Time		
Complex Processes:		
.Time & Motion		
.Concentration	Includes complex perceptual processes, meditational processes, & memory.	

3.4 DETERMINATION OF INTERFACE AND SYSTEM IMPACT

Each of the modifications or additions to the EDU was examined for system impact.

3.4.1 The primary impact examined concerned data management requirements (controls, displays, data processing and storage). Tables 3.2-1 through -7 contain notations regarding data management effects to be examined on a measurement-by-measurement basis. In many cases, scanning of the measurement or capability title together with knowledge of the EDU preliminary design was sufficient to determine whether there was an impact. Data management impact on other than an individual measurement basis could not be determined, since any total system requirement effect would require a mission definition from which time lines could be generated. However, the nature of the Engineering Development Unit as a ground test system is such that a specific flight-like profile is not envisioned. Instead, the exercise of the system is envisioned as having the flexibility to obviate the need for addition of equipments to handle workload peaks (see Task 7.0 report).

3.4.2 Other system impacts were considered secondary from a technical point of view and therefore were not directly analyzed. The modular design permits addition of modules in a relatively straightforward manner. Modest power and weight effects are not critical for an Engineering Development Unit. (The cost effect of integrating the additions and modifications into the EDU is factored in, however.)

3.5 BUDGETARY ESTIMATES AND RATIONALES

The budgetary estimates were based on previous experience in the development, construction and modification of similar equipment. Catalog values were used as guideline information for "off the shelf" items. In all cases, estimates of development costs and first unit costs included a factor for the cost of coordination and integration with the rest of the EDU system.

4.0 STUDY RESULTS

The results of the study are discussed below and are shown in Table No. 4-1, entitled, "Synthesized Measurements, EDU Capability and Cost Estimate." The following descriptions of the various headings in that table may facilitate its usage.

Column No. 1: ITEM NUMBER is a designation that organizes the numerous measurements into ten (10) functionally related groups, as described in 4.1 below.

Column No. 2: MEASUREMENT/FUNCTION required to conduct the FPE's in accordance with the stated guidelines.

Column No. 3: MEASUREMENT APPROACHES indicates the equipment or technique that is necessary to conduct the prescribed measurement.

Column No. 4: EDU CAPABILITY CATEGORY refers to the three categories of capabilities of the EDU to satisfy the measurements, and the necessary steps to correct any deficiency, namely: (1) no change, (2) EDU equipment modification, (3) new equipment required.

Column No. 5: COMMENTS refer primarily to the implications of the category that is shown in Column No. 3 (e.g. type of modification, new equipment required, etc.).

Column No. 6: COST ESTIMATE is given in terms of dollars for development test followed by the initial unit manufacturing cost, including integration into the system.

4.1 REQUIRED MEASUREMENTS OR FUNCTIONS

The analysis resulted in the identification of ten functionally related groups of measurements or functions, as shown below:

1. Environmental conditions are associated with the controlled parameters under which the experiment is to be conducted. For instance, noise (acoustical), vibration (structural), and micro-gravity variations (acceleration) constitute important correlation measurements in most biological experiments, since the measured disturbances may represent cues that adversely influence the experimental results.

2. Microscopy encompasses a variety of optical capabilities for on-board observations.

3. Photography and Television consist of monitoring and recording equipment for visual data, including the capability for on-board photographic processing.

TABLE No. 4-1
SYNTHESIZED MEASUREMENTS, EDU CAPABILITY and COST ESTIMATES

ITEM NO.	MEASUREMENT/FUNCTION	MEASUREMENT APPROACHES	EDU CAPABILITY* Category	COMMENTS	COST ESTIMATE
1.0	Environmental Conditions [1]				
	Temperature	Thermistors	(1)		
	Pressure - total	Transducer system	(1)		
	Partial Pressure	Gas Spectrometer/Chromatograph			
	O_2		(3)	See Mass Spectrometer /	
	CO_2		(3)	Gas Chromatograph	
	NH_3		(3)	-- #7a Chemical	
	H_2O		(3)	Analyses	
	CO		(3)		
	Trace contaminants		(3)		
	Acceleration (10^{-4}G range)	Steady-state Acceleration Transducer	(3)	Steady state and dynamic acceleration	200K Dev. /100K per unit
	Vibration	Dynamic Accelerometer	(3)	measuring device to be developed for low signal range	
	Noise	Acoustical Sensor	(1)		
	Radiation	Dosimeters	(2)	Modifications to RDM	40K Dev. / 60K per unit
	Illumination	Light intensity meter	(3)	Recording Photometer	12K Dev. / 20K per unit
	Particulate Concentration	EDU particle detector module	(2)	Limited mods to Particle Detector Module	Refer to cell counter under #5
2.0	Microscopy				
	Dissecting 2-200X	*Dissecting microscope*	(3)	Limited modifications to OTS items [2]	20K Dev. / 12K per unit
	Light $10\text{-}10^3$X	-- --	(1)		
	Phase $10\text{-}10^3$X	-- --	(1)		
	Interference $10\text{-}10^3$X	Interference microscope	(2)	Limited modifications to OTS items	30K Dev. / 15K per unit
	Fluoresence $10\text{-}10^3$X	Fluorescence microscope	(2)	Limited modifications to OTS items	60K Dev. / 30K per unit
	Dark Field $10\text{-}10^3$X	Dark Field microscope	(1)		
3.0	Photography / TV	Standard camera systems with exceptions as noted in "comments"			
	Polaroid Photography		(3)	Limited modifications to OTS items (additional evaluation may be required for flight unit--especially with regard to safety)	15K Dev. / 5K per unit
	35 mm		(1)		
	Time lapse		(3)	Potential use of current flight	
	High speed		(3)	equipment to be considered	50K per unit using
	Normal Cine		(3)		existing Flight Version
	High Resolution Color TV		(1)		
	Black-white TV		(1)		

[1] Environmental monitors provide general environmental monitoring--Experiment specific sensors provided in experiment "suitcase" to be interfaced with IMBLMS Data Management

[2] OTS items - Off the Shelf items

*CODE: (1) EDU has the capability to perform the measurement; no modifications required
(2) EDU requires modification to perform the measurement
(3) New equipment must be added to perform the measurement

TABLE No. 4-1 (continued)

SYNTHESIZED MEASUREMENT, EDU CAPABILITY and COST ESTIMATES

ITEM NO.	MEASUREMENT /FUNCTION	MEASUREMENT APPROACHES	EDU CAPABILITY * Category	COMMENTS	COST ESTIMATE
4.0	Data Collection and Handling				
	Oscillographic Recording	Strip - chart recorder	(1)		
	Standard Oscilloscope Monitoring	CRT	(1)		
	Persistence Oscilloscope Monitoring	CRT (Persistence)	(1)		
	X-Y Recording	X-Y Chart Recorder	(1)		
	Digital Recording	Recorder	(1)		
	A-D conversion	A-D Converter	(1)		
	Digital Data Storage	Memory Bank	(1)		
	Magnetic Tape Recording	Multi-speed Tape Recorder	(1)		
	Weight/Mass Measurement	Small mass measuring device (SMMD)	(1)	Assumes availability of Small Mass Measurement Device (SMMD)	
5.0	Specimen Handling and Dissection	Surgical Kit	(3)	Limited Modifications and additions to current surgical tools	20K Dev. / 10K per unit
	Micromanipulation	Micromanipulator Device	(3)	Limited modifications to OTS	14K Dev. / 8K per unit
	Cryogenic Microtomy	Microtome (temperature controlled)	(3)	Modifications to OTS and	70K Dev. / 70K per unit
	Freeze Drying	Freeze dryer	(3)	Development Engineering Estimate	150K Dev. / 150K per unit
	Refrigeration	Refrigerator	(1)		
	Freezing	Freezer	(1)		
	Storage	Modular containers	(2)	Configuration/experiment dependent	TBD
	Storage during return	Modular containers	(1)	Ambient, Refrigerator and freezer capability	
	Cell Counting	Particle Detection Module	(2)	Modifications to PDM	40K Dev. / 100K per unit
	Sterilization		(1)		
	Isolation of Biological Organisms	Isolation Function of MDOM	(1)		
	Fluid Acquisition and Preparation		(1)	B-4 SAPM (Sample Acquisition and Preparation Unit)	
	Specimen Handling	EDU/MDOM	(2)	Modified MDOM (Separate Unit)	50K Dev. / 150K per unit
6.0	Radioactive Material Storage	----------	(3)	Evaluation of Radiation hazards	50K Dev. / 50K per unit (engineering estimate)

* CODE: (1) EDU has the capability to perform the measurement; no modifications required
(2) EDU requires modification to perform the measurement
(3) New equipment must be added to perform the measurement

TABLE NO. 4-1 (continued)
SYNTHESIZED MEASUREMENTS, EDU CAPABILITY and COST ESTIMATES

ITEM NO.	MEASUREMENT/FUNCTION	MEASUREMENT APPROACHES	EDU CAPABILITY * Category	COMMENTS	COST ESTIMATE
7.0	Chemical Analysis				
	Spectrophotometry	Spectrophotometer	(1)		
	Gas Chromatography	Gas Chromatograph	(3)	Modified off-the-shelf equipment	100K Dev. / 100K per unit
	Mass Spectrometry	Mass Spectrometer	(2)	Evaluation of improved spectrometers is now in process; accurate cost estimates are not available.	50K Dev. / 50K per unit
	Electrophoresis	Electrophoresis Unit	(3)		100K Dev. / 200K per unit
	Centrifugation	Centrifuge	(2)	Modifications to SAPM (Sample Acquisition and Preparation Module)	30K Dev. / 50K per unit
	Manometry	Transducers	(3)	Five Ranges to provide broad capability--Modifications to OT5 items	20K Dev. / 40K unit
	Polography	Polograph	(2)	Modifications to Specific Ion Analyzer and Blord Gas Analyzer	70K estimated development cost--possible additional electrodes[1]
	Radiation Detection	Radiation Counter for α, β and γ	(2)	SOW calls for Gamma only--alpha and Beta type TBD	100K Dev. / 200K unit (engineering estimate)
	Osmometry	Osmometer	(3)	TBD -- current types involve solution freezing/boiling Fluid handling problem --Refractometer to be considered for some applications, but experiment dependent	
	ph Metering	Specific Ion Analyzer	(1)		
	High Temperature Heating	Oven	(3)	Potential problem due to limited energy source --(consider Solar/Nuclear energy)	40K Dev./ 20K per unit
	Fluid Containment		(1)		
	Mixing of Substances		(2)	Modifications to SAPM	20K Dev. / 40K per unit
	X-Ray Radiology	X-Ray Diffraction Process	(1)	Possible use of clinical X-Ray	
8.0	Activity Sensing	Must be tailored to the specific biological specimen	3a		

*CODE: (1) EDU has the capability to perform the measurement; no modifications required
(2) EDU requires modification to perform the measurement
(3) New equipment must be added to perform the measurement

** a = Sensors and electrodes specific to individual experiments are responsibility of experimenter and are to be furnished as part of experiment "suitcase"--EDU will handle all signals and data with appropriate interfacing

[1] Current capability: pO_2 HCO_3 K^+ Ca^{++} pCO_2 Cl^- Na^+ ph

TABLE NO. 4-1 (continued)
SYNTHESIZED MEASUREMENTS, EDU CAPABILITY and COST ESTIMATES

ITEM NO.	MEASUREMENT FUNCTION	MEASUREMENT APPROACHES	EDU CAPABILITY * Category	COMMENTS	COST ESTIMATE
9.0	Measurements Requiring Instrumentation of Vertebrates and Invertebrates	Specialized, tailored to the specific experiment and biological specimen			
	Respirometry		3a**		
	ECG		3a**		
	EMG		3a**		
	Calorimetry		3a**		
	Cardiovascular Pressure and Flow	Pressure Transducer and F/G	3a**		
	Temperature		(1)		
10.0	Medical Research Physiological Measurements				
	VCG	Cardiovascular Module	(1)		
	EEG	Neurological Module	(1)		
	EOG	Neurological Module	(1)		
	Plethysmography	Plethysmograph	(1)		
	Sphymomanometry	Sphymomanometer	(1)		
	Voice Recording	Tape Recorder	(1)		
	LBNP		(1)		
	RLC		(1)		
	Ergometer		(1)		
	Respiration Flow Rate	Cardiovascular Module	(1)		

*CODE: (1) EDU has the capability to perform the measurement; no modifications required
(2) EDU requires modification to perform the measurement
(3) New equipment must be added to perform the measurement

** a = Sensors and electrodes specific to individual experiments are responsibility of experimenter and are to be furnished as part of experiment "suitcase" -- EDU will handle all signals and data with appropriate interfacing

4. Data Collection and Handling includes electronic data monitoring, formating, recording, and analog-to-digital conversion of pre-conditioned analog signals from experiment sensors. The capabilities of the EDU meet all the information management requirements derived from the Blue Book.

5. Specimen Handling and Dissection encompasses freezing and sterilization, in addition to the equipment required for manipulation of specimens.

6. Radioactive Material Storage is required for radiation studies such as isotopic trace analyses.

7. Chemical Analysis provides the capability to perform comprehensive on-board analysis of a large variety of substances and is comparable to the capabilities of a well equipped bio-research laboratory on the ground.

8. Activity Sensing relates to the surveillance of biological functions and motions of the vertebrate and invertebrate experimental subjects during critical phases of the test. Including Photography and TV, which are covered under Item No. 3, special devices will be required to provide this capability for each specific experimental requirement in question.

9. Measurements Requiring Instrumentation of Vertebrates and Invertebrates implies a variety of specialized sensors, electrodes and signal conditioners, the characteristics of which are highly dependent on the specific biological species.

10. Medical Research Physiological Measurements include many of the functions of IMBLMS, and thus are adequately satisfied with the EDU equipment.

4.2 REQUIRED CHANGES TO THE EDU

The main additions and modifications to the EDU, as indicated in Table 4-1, are as follows:

a. Addition of a gas chromatograph to operate in conjunction with a modified EDU mass spectrometer, to satisfy the requirements for precise chemical analysis and partial pressure measurements.

b. Addition of a dissecting microscope, to complement the existing capabilities in the EDU.

c. Incorporation of on-board film processing capabilities for quick-look photographic data analysis and spot-check verification that the film data gathered during the mission is adequate.

d. Addition of a micromanipulator device to be used in special places of cells and tissues and plant research.

e. Modification of the EDU Sample Acquisition and Preparation Unit for the handling of biological specimens.

f. Addition of storage provisions for radioactive materials.

g. Modification of specific ion analyzer and blood gas analyzer for photography measurements.

4.3 COST ESTIMATE

This section deals with the cost estimates for equipment in Category 2 or 3, according to the results presented in Table 4-1. The costs for modifications and new equipment are presented as sub-totals for each of the ten measurement categories (identified as Items 1 through 10 in Table 4-1). Comments and rationale are given, where appropriate, concerning these costs.

4.3.1 Environmental Condition Measuring Equipment

Development Costs: $252,000

First Unit Costs: $180,000

Comments: 1. Approximately three-fourths of this cost is related to the acceleration and vibration sensors, which need development for very low steady state and dynamic acceleration levels, in the order of 10^{-2} to 10^{-5} G's. Additional analyses and experiment specifications are needed to determine an accurate cost for these sensors.

4.3.2 Microscopy Equipment Costs

Development Costs: $110,000

First Unit Costs: $ 57,000

Comments: 1. The reference for the cost estimate of the dissecting microscope is the American Optical Company price, including stereo zoom, light source, supplementary lenses and accessories.

2. Modification of existing EDU microscope for interference and fluorescence observation require the incorporation of an interference tube, contrast tube, power supply, and a light source. Reference for this estimate is Zeiss equipment.

4.3.3 Photography/TV Equipment Costs

Development Costs: $ 15,000

First Unit Cost: $ 55,000

Comments: These estimates are based on present availability of high quality flight proven equipment. Some development is necessary to eliminate the operator's contact with chemicals during the processing of the film.

4.3.4 Data Collection and Handling

No cost since all entries are in Category 1.

4.3.5 Specimen Handling Equipment Costs

Development Cost: $344,000

First Unit Cost: $ 488,000

Comments: 1. The cryogenic microtone cost estimate includes the microtone, cutting accessories, provision for de-icing, quick freeze attachments, and optional sterilization cycle, and should be adaptable for use in the EDU Micro-biological/ Direct Observation Module (MDOM).

2. The freeze-dry equipment cost estimate is based on a substantial development program for adaptation of the process to zero G environment.

3. Estimates for the cost of the cell counter equipment are based on information from Particulate Data, Inc.

4.3.6 Radioactive Material Storage Costs

Development Cost: $ 50,000

First Unit Cost: $ 50,000

Comment: Cost of the system is based on providing basic storage and handling for radio-isotopic use by the experimenters. Specific experiment information will be needed to provide a refined cost estimate.

4.3.7 Chemical Analysis Equipment Costs

Development Cost: $530,000

First Unit Cost: $ 700,000

Comments: 1. Estimates for Electrophoresis consider power supply, individual separation units, densitometer/recorder, and provision for immuno-electro-phoresis. Reference: Millipore Phoroslide System.

2. Estimates for Manometry consider general purpose precision transducers. Reference: Statham Instruments

3. The requirements for Polarography are interpreted to imply additional electrochemical electrodes such as ion-selective electrodes. Reference: Orion Scientific, Inc.

4. Requirements for Radiation detection include the addition of Alpha and Beta sensors together with appropriate output interfaces to complement the existing gamma detector. Reference: Hewlett Packard Co.

5. The operation of standard osmometry instruments involve gravity-dependent sample introduction--therefore, R&D will be needed to make the process independent of gravity. The cost estimate considers the possible use of refractometry as a substitute method.

Note: Measurement items No. 8, 9, and 10 do not require costing and therefore are not included in Section 4.3.

4.4 INTERFACES AND SYSTEM IMPACT

No additions to the EDU data management capability are required based on the identified measurement and equipment modifications and additions (using the ground rule of no duplication of equipment based on timeline requirements), and no other primary effects on the system were encountered.

Interface specifications will be required to be placed on experiment-unique equipment that is to utilize the EDU as a basic facility. The specifications will insure that the electrical signal characteristics, biology sample physical characteristics, and radiative properties. (e.g., heat radiation, electromagnetic radiation, etc.) of the added or modified equipment is compatible with the present concept of the EDU design. Thus, the interfaces will be attainable with the present EDU configuration, and the system impact on the EDU is restricted to the changes as described in Section 4.2 and Table 4-1 of this report. One example of the need for placing interface requirements on the experimenter's experiment-unique equipment is shown in Table 4-1, Items 8 and 9, Measurements Requiring Instrumentation of Specific Organisms. It is noted that sensors and electrodes specific to the individual experiments will be the responsibility of the experimenter and are to be furnished as part of the experiment "suitcase."

5.0 CONCLUSIONS

The results of this analysis indicate that -- with the addition of equipment and modification of some of the EDU equipment -- it will be feasible and practical to use the EDU as the central facility for research in the Life Sciences. A preliminary estimate of the total cost of these changes is $1.3 M for development and $1.53M for the first units. This estimate does not include specialized experiment-unique equipment, since it is assumed that these will be part of the particular experiment package (or experimenter's "suitcase").

Environmental conditions monitoring and chemical analysis will require the addition of a gas chromatograph. This can be a modified off-the-shelf model, which will be complementary to the present EDU spectrophotometer.

The present microscopes in the EDU require minor modifications and the addition of a dissecting microscope. The present photography and TV capabilities in the EDU require the addition of polaroid photography and cine photography (variable time-lapse).

The EDU data collection and handling capabilities are amply adequate to satisfy the requirements of each of the "Blue Book" functional program elements. The specimen handling capabilities of the EDU are adequate, but require additional items such as a surgical kit for dissection, and a micromanipulating device.

GENERAL ELECTRIC

Space Division / Headquarters: Valley Forge, Pennsylvania ☐ Daytona Beach, Fla. ☐ Cape Kennedy, Fla. ☐ Evendale, Ohio ☐ Huntsville, Ala. ☐ Bay St. Louis, Miss. ☐ Houston, Texas ☐ Newport Beach, Calif.